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Effects of Central Fixation on the Alpha Rhythm in Eccentrically Fixating Amblyopes

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Abstract

EEG alpha rhythm amplitudes of six eccentrically fixating amblyopes between 8-39 years of age were studied during habitual fixation and central fixation with the amblyopic eye while the non-amblyopic eye was patched. Central fixation was achieved by utilizing an entopic phenomenon called Haidinger Brush and placing this brush-shaped image on a small letter. For each subject, habitual fixation of the amblyopic eye was considered the control, and attempting to centrally fixate with that eye was designated as the variable. The same procedure was repeated for the non-amblyopic eye of each subject. The latter was considered a second population, and the results were used to study the extent of psychological artifacts that could influence the results of this study. After one month of testing (up to 12 sessions for each subject) the amblyopic eye showed decreased amplitude of alpha rhythm when attempting to centrally fixate. However, the same result was obtained in the second population (the non-amblyopic eye) which suggests that some of the decrease in the amplitude may be the result of psychological factors such as motivation, anxiety and alertness while attending to a task.

Introduction

Amblyopia is a common clinical finding that occurs in nearly 2 percent of the population. This visual abnormality reveals itself as a decreased visual acuity that is not correctable by optical means and is not due to an active pathological disorder.

EEG alpha rhythm is a brain wave, usually with a frequency of 8-12 c/sec in adults, most prominent in the occipital areas, present most markedly when the eyes are closed, and attenuated during vigilence, especially visual* attention. Hallmark (1978) in his study with biofeedback correction of unsteady and eccentric fixation in amblyopia associated with strabismus and anisometropia suggested that lack of visual feedback appears to be the cause of micro-eye movements. These micro-eye movements were further classified into three groups: 1) micro nystagmoid 85/sec 10" of arc, 2) slow drifts of random directions, and 3) small, periodic, rapid saccades 5' of arc. In amblyopia these movements are exaggerated. He further showed in his investigation that foveal fixation could result in less micro-eye movements (steady) and variable non-foveal fixation in more (unsteady). Lippold (1973) investigated these small eye movements (he

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*This is a definition of α-rhythm as suggested by the Terminology Committee of International Federation for EEG and Clinical Neurophysiology (Storm van Leeuwen, et al., 1966).

called them ocular tremor) and their correlation with alpha rhythm. He found striking similarities between these wave forms in terms of frequency and amplitude, both tending to wax and wane at about the same time.

The present study is concerned with investigation of alpha attenuation of eccentric fixation amblyopes when attempting to centrally fixate.

Problems Associated with the Study

A critical evaluation of normal EEG rhythm of human adults is fraught with difficulties. The majority of studies available in medical literature about alpha rhythms are based upon examination of patients with neurological and/or psychiatric illnesses. It is difficult to compare the results of these studies because of a variety of factors including major dissimilarities between populations investigated, differences in instrumentations and technique, a lack of uniform quantitative criteria for identification of these rhythms, the influence of various disease states and possibly the effects of drugs and/or other treatments.

Discovery and Principal Features of Alpha Rhythm

Alpha rhythm was first observed by Hans Berger in 1929. He initially described this wave as "waves of the first order" and felt that they arose from the entire cerebral cortex. This later designation was contrary to the belief of other authors such as Adrian and Mathews (1934) who expressed the belief that alpha waves originated in the occipital cortex. Berger also pointed out in 1935 that anxiety and heightened attention to non-visual stimuli attenuated the α-waves in blind subjects.

Inter-individual Variability and Long-Term Correlates

Many authors have conducted studies to find a correlation between different traits of personality with abundance, activity or amplitude of alpha waves. Personality traits studied were cyclothymic vs. schizothymic (Lemere, 1936), passive-dependent vs. "consistent, well directed, freely indulged drive to activity" (Saul, et al., 1937), extroverts vs. introverts (Henry & Knott, 1941) and on the basis of anxiety-proneness (Vlett, et al., 1953). Other authors took alpha index and alpha amplitude of their subjects and tried to find a correlation between them with the scores from personality inventory tests (Gastout, 1959; Mundy-Castle, 1955; Savage, 1964 & Young, 1971). The results were that persistent (high index) alpha was found among cyclothymic, passive-dependent and less anxiety proned individuals. Low indices (non-persistent) alpha rhythm observed in schizothymic, consistent, active and more anxiety proned people. Extroverts and verbalizers were found to have low amplitudes. Other approaches to inter-individual differences in alpha activity have sought correlations with intelligence. These studies (Berger, 1931-8; Gastaut, 1960; Henry, 1944 & Shagass, 1946) failed to show encouraging correlations between any measures of alpha and intelligence test scores.

Golla, et al., (1943) made a classification of alpha activity based in part upon its abundance or scarcity and in part upon its reactivity. He distinguished three types of individuals on the basis of their alpha activity: P, M and R.

1. P (plus)--subjects displayed a persistent alpha rhythm which was resistant to attenuation by mental efforts; these persons were said to use predominantly auditory, tactile or kinesthetic rather than visual imagery.

2. M (minus) individuals showed little alpha activity and used essentially visual imagery.

3. R (responsive) type persons exhibited an alpha rhythm readily attenuated by states of tension, and visual and other stimuli.

Short and Walter (1954) studied M, P and R subjects and correlated EEG types with skills in learning finger mazes. They observed that type M and type P subjects showed shorter exploration times, whereas individuals of type R required longer exploration times and demonstrated incorrect responses related to the manifestation of alpha bursts in their EEG. These authors expressed the belief that subjects could be categorized on the basis of the degree of consistency of their mode of imagery. Those persons who were consistent tended to be the most successful. The study was replicated on a second group of individuals, and the data obtained were found to be in accordance with the initial investigation. It should be emphasized that all these studies of the relationships of imagery to alpha activity rest upon the assumption that there are constant individual differences in types of imagery as well as of EEG.

Blatter (1960) in his study classified individuals as "visualizers"; those who tended to have smaller alpha amplitude but higher frequencies and "verbalizers," those with larger amplitude and lower frequencies.

Intra-individual Variability and Environmental Change:

Amplitude of alpha is reduced by visual, auditory and tactile stimulation (Berger, 1930). For visual stimuli Bagchi (1937) found that the alpha blocking time was directly related to stimulus intensity. It was also observed that the duration of the stimulus may influence the latency as well as the time required for alpha to return to pre-stimulus levels. Repeated presentation of a monotonous stimulus leads to "adaptation" which by presentation of a novel stimulus a recovery of response is obtained resembling that of the initial stimulus. This phenomenon might be a measure of "disinhibition" (Knott & Henry, 1941). Meaningful stimuli delivered visually produce longer periods of blocking than lights of corresponding intensity (Travis & Knott, 1937). Berlyn and McDonnell (1965) reported longer duration of alpha blocking with presentation of more complex and incongruous visual material. No adaptation was demonstrated and no change was seen when motivation to attend to the stimuli was varied.

Reaction time and latent blocking of alpha rhythm by auditory stimuli was studied by a number of authors with no definite correlations findings. In 1963 Surwillo found high correlations between RT to auditory stimuli and average

EEG period during the RT interval. These results led him to suggest that "brain wave cycles may form the unit of time in the programming of events" in the CNS. Another investigation by Surwillo (1964) examined "decision time," i.e., the time necessary to choose between two alternatives. Subjects with slower alpha frequencies had longer decision times. Boddy (1971) was unable to confirm these findings in a study using automated power spectra of the EEG and both auditory and visual stimuli. These results were interpreted as suggesting that changes in level of arousal might account for Surwillo's findings.

Intra-Individual Variability and Psychological Processes

One of the most intriguing phenomena of the human EEG is the waxing and waning of the alpha rhythm as time passes. Berger (1930) suggested that these recurring voltage changes corresponded to fluctuations of attention or waves of apperception.

According to observations made by Travis (1937) "mental blankness is associated with larger amplitude alpha." Martinson (1939) investigated changes in alpha activity, measured by frequency and alpha index, during experimental conditions designed to promote "mental blocking."* Interestingly,

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*The subjects were given the task of naming the opposite of a word delivered verbally by the experimenter and to press a key simultaneously. All individuals selected had a dominant alpha index (i.e., about 75). Three series of stimuli were given one of which involved easy opposites, another difficult opposites and the third mixed easy opposites and words to which there were no opposites. Mental blocking was defined as either prolonged response time or inability to give an opposite.

there were no remarkable changes in alpha activity related to "mental blocking" produced in this manner. "Mental blankness" and "mental blocking" are not identical states. In situations requiring an impossible recall, it is possible that the subject would not be blank but would rather bring an even greater degree of attention to bear on the problem. Other authors have done investigations using "emotional" words vs. "neutral" words presented to their subjects and each time observing alpha amplitude and alpha blocking (Dixon & Lear, 1936; Heinemann & Emrich, 1970). An active "inhibitory" process was revealed by or related to alpha amplitude (for "emotional" words). The total duration of alpha blocking is, for a given subject, significantly longer for emotional than neutral words.

Durup and Fessard (1935) using controlled experimental modification of intra-individual alpha variability observed that when an auditory stimulus normally ineffective in blocking the alpha rhythm, was paired with a visual stimulus, the auditory stimulus acquired the property producing alpha blocking. This concept was utilized by various authors to design experiments using visual stimuli as a "conditioning" tool for learning. For example, Milstein (1965) was able to show that when tone and light were paired with the eyes open in the absence of an alpha rhythm, subsequent tests for "conditioning," i.e., presenting the tone alone with the eyes closed, yielded increased blocking to the tone alone.

Intra-Individual Variability and Attention

Berger (1930) was aware that the degree of attention to the subject correlated with the amplitude of alpha rhythm. This topic was reviewed by Mulholland (1969), who employed a rather unique method of facilitating alpha activtiy by deviating the eyes into an extreme upward gaze, an action which is uncomfortable and demands continuous effort (Mulholand & Evans, 1965). The point of significance was that the facilitation of alpha rhythm so induced continued in spite of the mental activity of the subject during this time, including that involved in the inspection and reporting of a visual after image. It was also possible to enhance the alpha rhythm in a repetitive manner by slowly elevating the gaze and returning it to central vision at a rate of less than 1/sec. Mulholland argued that in view of the high level of attention required for the performance of this maneuver, the alternating augmentation and attenuation of alpha activity could not be explained solely by changes in attention. Fenwick and Walker (1969) further investigated that extreme deviations of gaze to the left, right, or downward yielded similar results although for the whole group of subjects they tested, only deviations to the right gave consistent effects. Making recourse to a model of alpha rhythm which postulates that a pool of cortical cells, when synchronized, produces alpha activity, Fenwick and Walker proposed to add eye position to the list of factors capable of modifying such synchrony. They pointed out that the very act of extreme deviation of the eyes causes a shift in the focus of attention from details in the visual field. Alternatively or in addition, such eye deviation might be associated with neurophysiological activity which modifies the state of activity of the pool of neurons generating the alpha rhythm.

Inter-Individual Differences and Alpha Frequency

Alpha rhythm as viewed by Adrian and Yamagiwak (1935) is generated by a set of cortical neurons producing a gradient of activity maximal in visual areas. Presumably the greater the number of neurons which become synchronized to produce alpha, the greater the amplitude of the resulting potentials. Creutzfeldt, et al., (1969) examining EEG phenomenon, utilized alpha waves as a measure of "synchronization." These authors felt that there is a certain optimum level of "synchronization" that might be necessary and that "too much synchronization" might be incompatible with the performance of mental tasks.

Intra-Individual Variability and Voluntary Control of Alpha Rhythm

"Biofeedback" techniques were used to "train" subjects to increase their percent time alpha. Nowlis and Kamiya (1970) reported evidence of voluntary control of alpha activity by using auditory feedback. In this experiment "presence of alpha" was defined as alpha activity exceeding about 20 uv in amplitude. Subjects were asked to "try to figure out what made" the auditory signal turn on and off.

Pepper and Mulholland (1970) gave auditory feedback (410 c/sec) for alpha activity above 25 percent of its average value at rest and removed the feedback when it fell below 20 percent of the same measure while the subject had his eyes closed. They pointed out that "training" appeared to be more effective for inhibition rather than production of alpha activity.

Biofeedback techniques utilize psychological correlates of alpha enhancement as Nowlis and Kamiya (1970) and Brown (1970) have suggested that pleasant mood states accompany the "voluntary" increase of alpha rhythm. Amand, et al., (1961) found that the alpha rhythm was not only enhanced in Yogis practicing meditation but was also resistant to blocking by external stimulation.

The Study

Does α activity decrease when an eccentric fixator amblyope centrally fixates?

Subjects

Subjects were selected on the basis of fixation eccentricity. Nearly 40 people responded to an advertisement that called for amblyopes, only 10 were diagnosed as having eccentric fixation and from those 10, only 6 subjects stayed in the research project. Subjects' age ranged from 8 - 38 years.

Technique of Screening Variables

I. Case History: Subjects were interviewed as follows:

  A. Name, address, age, nature and age of onset of amblyopia, previous eye disease, injuries and surgeries, blurring, diplopia, headache, ptosis, birth defects, closing one eye, other problems.

  B. Previous Rx: glasses, contacts, VT (date and duration, problems trained, techniques in home or office and results).

  C. Family History of: glaucoma, cataracts, strabismus, blindness, hypertension and other conditions (neurological problems mentioned).

  D. General Health: medications taken, drug allergies.

II. Visual Acuity: distance and near--also used pinhole single line and single letter in dim illuminations for amblyopic eye.

III. Accommodation, extraocular eye moments, pupillary reactions.

IV. Special testings:

A. Visnoscopy: Measures angle of eccentricity (< E).

1. Monocular (RM and PVD) cover the non-testing eye .

   a. Observe:

      1. steady vs. unsteady
      2. central vs. eccentric

         a) foveal off center (1) degree or less
         b) para foveal (3) degrees or less
         c) para macular (5) degrees or less
         d) peripheral more than (5) degrees

   b. If steady EF ask the subject if the center of the target is straight ahead or off to the side: RM

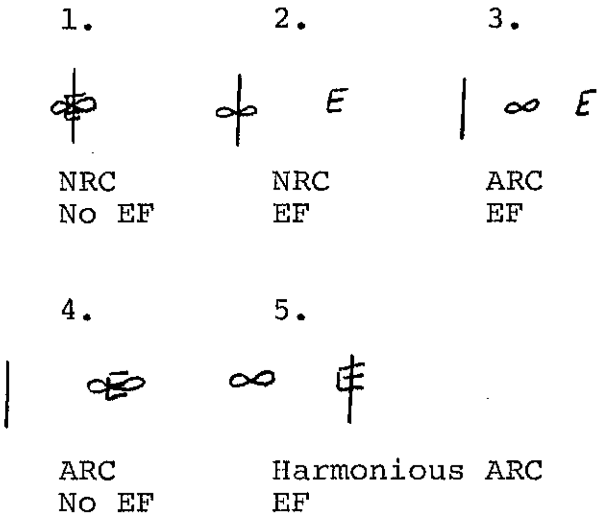
   c. Move the center of the target so projected on the fovea and ask the same question as b: PVD

2. Binocular: This is a quick test for assessment of the nature of retinal correspondence (ARC vs. NRC) while testing the EF eye, the subject holds a mirror close to medial canthus of the non-testing eye and through the mirror views a projected letter to the side. At the same time the examiner puts the center of the visuoscope of the fovea of EF eye. The patient is then asked if the letter is inside the circle (NRC) or off to the side (ARC).

B. Haidinger Brush* and After Image Transfer+: In this section of testing we are interested in finding out about both magnitude of EF and nature of retinal correspondence. This test also tells us about quality of response to HB: present, part missing or absent (central suppression possible). Subjects who were unable to view the HB (after all the adjustments possible were done) were not suitable to proceed and were dismissed. Patch the EF eye, put a vertical AI on the sound eye (using a camera flash with a vertical slit glued on it). Then patch that eye and unpatch the EF eye. Fixate on a letter on MITT (Macular Integrity Tester and Trainer) and record the positions of AI, HB and fixation letter.

* HB

\+ AIT



a.

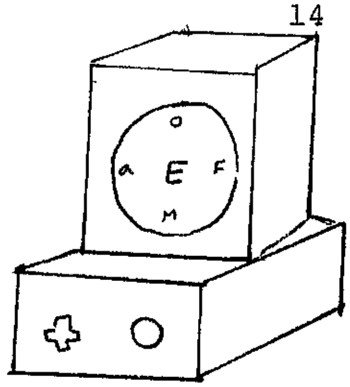


fig. 1
a) MITT
b) five possible responses
c) is the distance between HB and fixation letter

From five types of responses, only subjects with type 2, 3 and 5 were chosen to be trained.

In order to calculate the magnitude of EF, subjects were set 40 cm away from the MITT and were asked to draw a line at the position where HB was observed while looking at the fixation letter with the EF eye. d is the distance between fixation and the HB in cm.

$$EF = \frac{d}{.4} \text{ in prism diopters}$$

(to find EF in degrees multiply the above answer by 4/7). The magnitude calculated as above is far more accurate information than visuoscopy.

After presence of EF had been well established, other testings were done to determine other causative factors contributing to amblyopia:

V.

A. Refraction: Best RE was determined using spheres and cylinders.

B. Keratometry: Looking for high corneal astigmatism or distorted corneal surface (mires distorted).

C. Ophthalmoscopy: Investigation for any apparent pathological conditions, e.g., myelinated nerve fibers, optic atrophy, macular degeneration, nerve fiber layer dropout, etc.

D. Slit Lamp: Optical media were carefully examined: opacities in cornea, lens, vitreous.

E. Visual Fields: Tangent screen was used. Central and peripheral fields were carefully examined.

VI. Alpha Rhythm: Subjects who passed the screening and were found to be perfectly healthy with no medications and had healthy looking eyes without central suppression, were chosen to proceed with the research. The next step was to determine the state of their alpha activity with the eyes closed and eyes open (types P, M or R).

A. 20 seconds run with both eyes closed.

B. 20 seconds run with both eyes open.

C. Eyes closed, visualization and arithmetical problem solving.

Apparatus

The EEG alpha rhythm was monitored with OEU-4 while patients were fixating on the smallest letter they could read on a MITT screen. The strip chart was set at 25 mm/second. (See photograph, figure 2.)

The oscilloscope used in this experiment was Phillips D1015 dual channel with these modes of operation:

ch. 1 AC	.1 or .2 volts/div.
ch. 2 AC	.1 volts/div.
Trigger Level:	Turn in fully cw, pull out; or fully ccw and push in.
Trigger Switch:	Auto
Sec./Div.	.2 to 50 ms
Low Trig. Sw.	EXT
MAG and HOR Pos.	IN; adjust beginning edge of trace to left graticule.

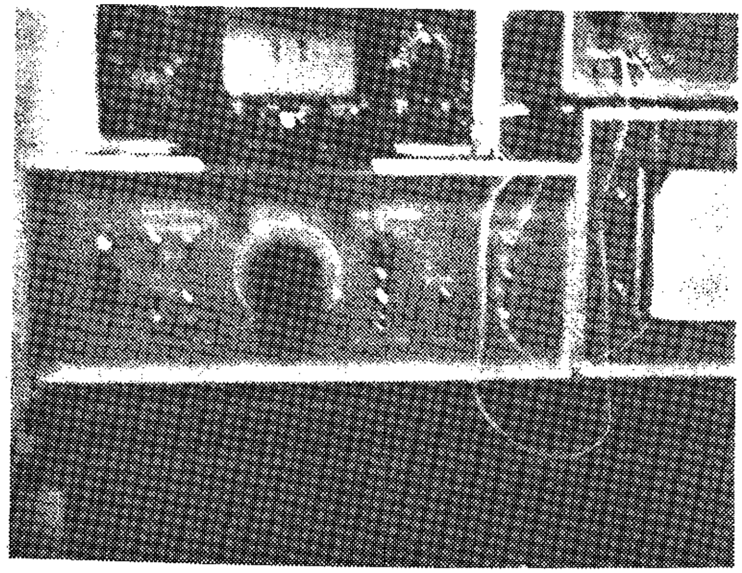


Fig. 2. The apparatus used in this experiment: OEU-4

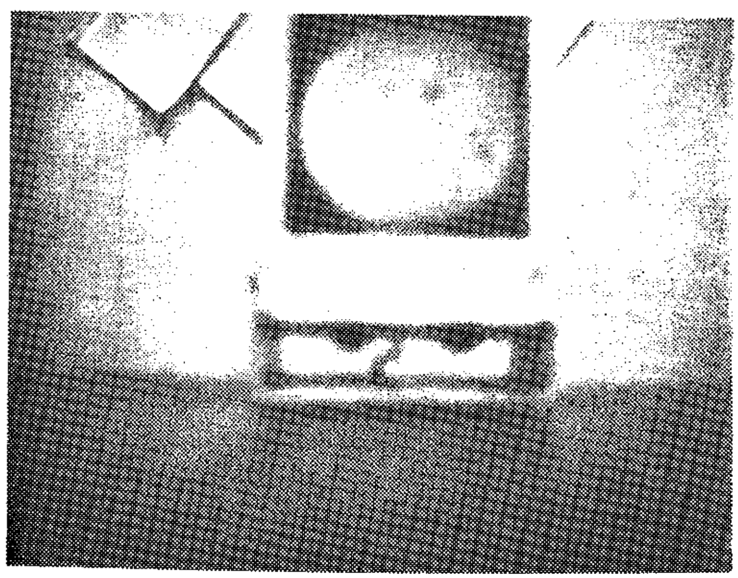
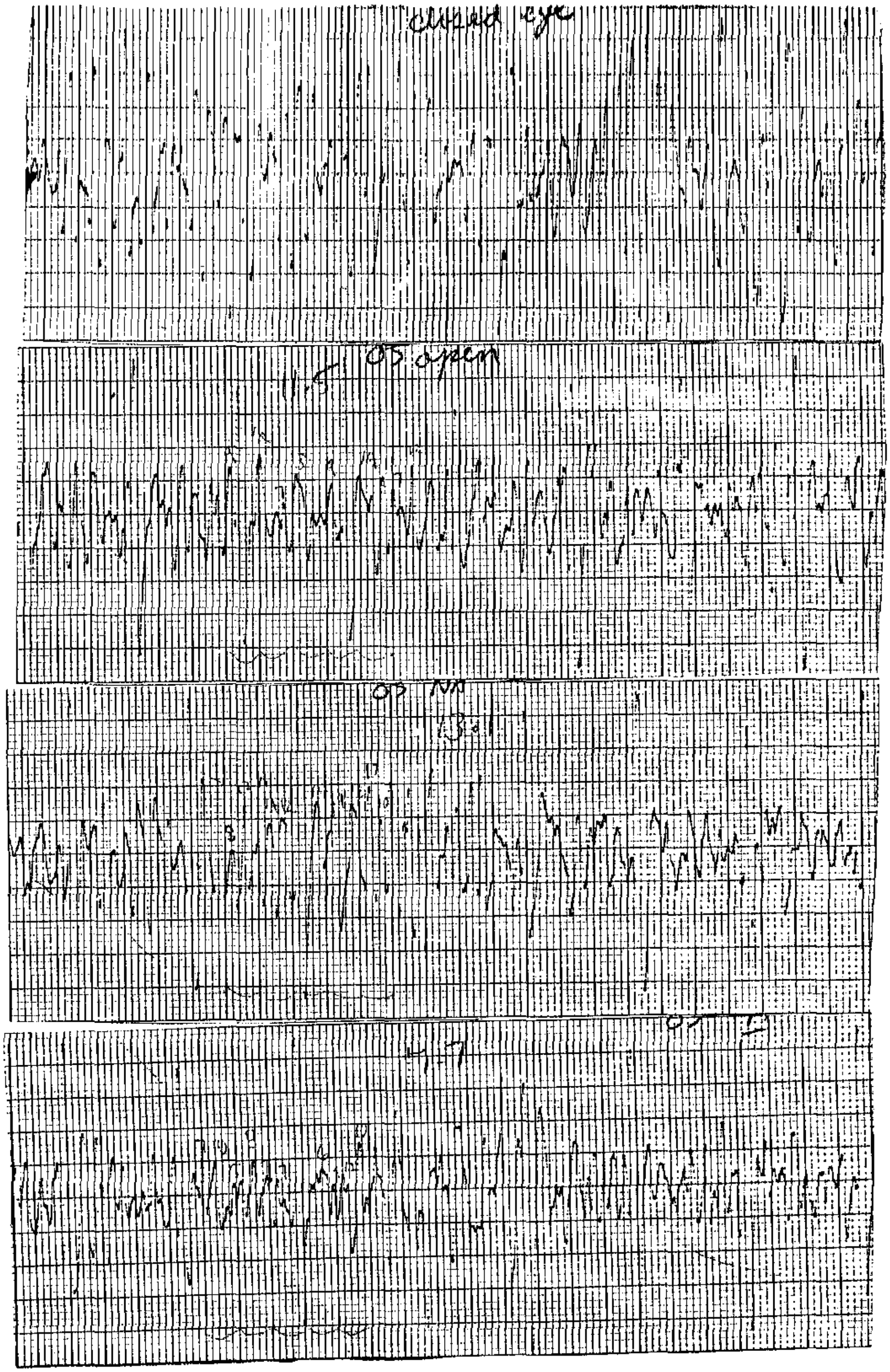


Fig. 3.. MITT unit



(a)

(b)

(c)

(d)

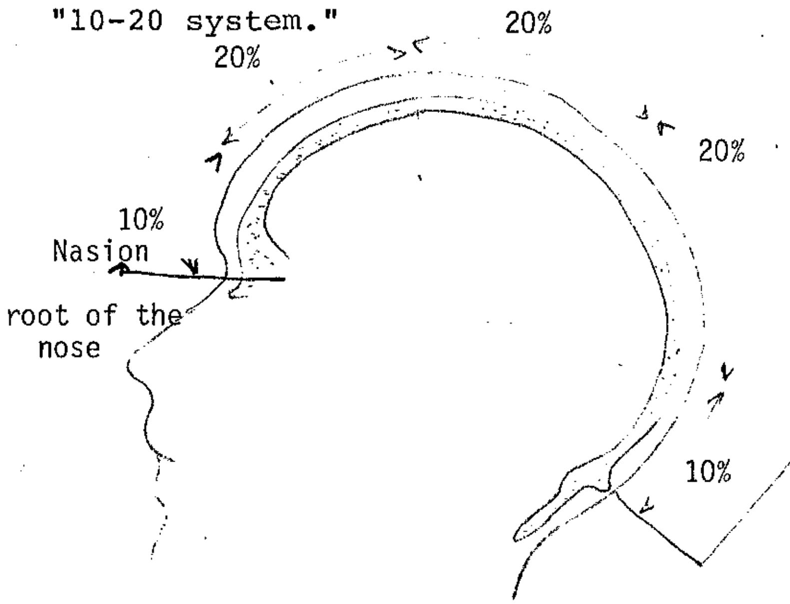
Fig. 4. An example of an EEG alpha rhythm strip chart for one of the subjects. (a)Eyes closed, (b) the amblyopic eye open, the subject is looking at a grey screen situated at 10 feet away, (c) the subject is looking at a letter on MITT screen with his amblyopic eye ("No Attempt" or "NA" or eccentric fixation or "Habitual fixation"), (d) the subject is attempting to place HB (Haidinger Brush) on the fixation target ("Attempt", "A", or central fixation).

Subject Preparation

1. Appointment: Every effort was made by experimenter and each subject to keep his/her three-times-a-week appointment at exactly the same time of the day. But in a few cases (M.L. and E.W.) due to conflict with their daily schedule this was not always the case.

2. Checking the Instrument: Switches were checked to be at the desired place.

3. Electrode Placement: The experimenter used Jasper's "10-20 system."



1. measure nasion to inion in EM
2. times 10% ⟶ gives you numbers of cm above inion (2.5 cms)

A cup electrode was placed at 10 percent above inion. "Earthing" was done by putting two clip-type electrodes on each earlobe. In all cases, in order to produce maximum conduction, the skin of earlobes and scalp at the side of recording, was cleaned with alcohol to remove dirt and grease and a special paste was used

4. The Room: Dim light was chosen to provide maximal visibility on the MITT screen. A gray screen was placed

at ten feet away in front of the subject. Unfortunately, the room was not well insulated against noise from hallway and pagings done by the receptionists.

5. Positioning the Patient: Patient was seated on the exam chair. The back, head and footrest were adjusted to provide good comfort for the duration of the examination.

Conduct of Recording

1. Reactivity

a. Arousal reaction (AR) or alpha attenuation could happen as a result of three conditions:

1) Reaction to visual attention

2) Reaction to noise and to attention with a patient who is very attentive, for example, listening to conversation or to the noise created by the instrument(s) or making an intellectual effort (a memory list or mental arithmetic), an arousal reaction can be seen even if the eyes are closed. For the sake of the quality of recording, the experimenter made all effort to record only during the time when the environment was fairly silent. Also in calculating the leverage amplitude, the "spikes" produced by noise were thrown out as artifacts.

3) Arousal reaction to anxiety. This type of arousal which is most common on the first exposure to the recording device is little by little factored out as the patient gains confidence. The experimenter had always reassured the patient that there was no abnormalities to be measured.

b. Other Artifacts: Considerable effort was done to minimize the following artifacts:

1) Movement artifact: produced indirectly by the movement of experimenter in the vicinity of subject: swinging a cable, bumping the chair, etc. This could result in appearance of anomalous bursts in the activity.

2) Respiration artifacts: the subjects were made aware of the possibility of hypo or hyperventillation when trying hard to maintain a fixation. They were instructed to breathe normally as concentrating on doing a task.

3) Ocular movements: since subjects are getting a feedback of where their eyes are pointed (viewing HB and trying to place it on a letter), this factor is not very significant in this research. In other experimental designs EOG might be needed to monitor eye movements (Lippold, 1973).

4) Muscular contractions did not appear to be a significant factor in this experiment, either. The subjects all appeared very calm and cooperative. No signs of neurological disorder was present in any of the cases. However, a short instruction was given as follows: "trying to keep silent while recording and keep any body movement to a minimum."*

5) A faulty contact in the path between the skin and the amplifier input which acts as a capacitor. This would result in spikes, sharp waves and crenellations.

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*One should avoid giving too much instructions. Hector (1980) in her manual (EEG Recording) shows how this could put a patient who is afraid of doing the wrong thing, into a state of "arousal reaction" for the entire length of the recording.

6) Electrodes defective (or fallen off): this would result in a large anomalous deflections.

Frequency of Alpha Wave

α-activity range is 8-12 cycles/sec. Therefore, for speed of chart at 25 mm/sec and average activity being 10 cycles/sec, then 10 cycles should be completed in 25 of the smallest divisions on the strip chart or 5 of the larger boxes.

Amplitude of Alpha Rhythm

Due to the fact that amplitude of alpha waxes and wanes throughout any period of time, it is a matter of subjective judgement to select a typical stretch of recording for measurement. There are a number of different ways to measure the amplitude (Lippold: The Origin of α Rhythm).

(a) Measurement of peak-to-peak amplitude, by hand from the records. Mean amplitude per wave could be found if necessary.

(b) Measurement of maximal amplitude in a given length of record. This method suffers from some degrees of inaccuracy due to artifacts being able to produce one single large amplitude wave.

(c) Planimetry: The area "enclosed" is measured with a planimeter.

(d) Fourier analysis.

(e) Integration (Shaw, 1967).

(f) Amplitude Histogram: Using Biomac 1000 fixed-program computer.

Method (a) was used in this experiment as follows:

1. On each days run, an arbitrary period of 1 second was chosen (25 of the smallest divisions at speed of chart 25 mm/sec) which was kept constant throughout the entire reading for that subject, on that day.

a. Eyes closed.

b. Sound (non-amblyopic) eye open looking at distant opaque screen.

c. Sound eye open.

1. Attempt to put the brush on the smallest letter on the screen.

2. No attempt.

d. Eyes closed.

e. Amblyopic eye open looking at distance.

f. Repeat entire procedure for amblyopic eye.

2. On each of a-f take the average amplitudes.

3. In order to reduce signal-to-noise ration and eliminate certain intra-individual variables and for practical purposes in calculations, ratios used for each eye were:

a. Average amplitude of no attempt/average amplitude eye open looking at distance.

b. Average amplitude of attempt/average amplitude eye open looking at distance.

The intra-individual variables are many. However, they can be grouped into four classes:

a. Those that cancel out by above ratios: Auditory, proprioceptive, tactile, passive movements of body and eyes, personality, intelligence and abundance or scarcity.

b. Those variables that might not cancel out are: Accommodation, convergence, attention.

c. The third variable or probable group of variables are what it is that is different in "attempt run" rather than "no attempt run." If such a variable existed, it could arise from the following factors:

1. Cortical neuron activites: the greater the number of neurons, the more potential for alpha activity (attenuation with attention) due to larger number of neurons being "synchronized" (Creutzfeldt, 1969).

According to Lippold (1973) ocular tremor which usually increased the amplitude of alpha wave, should not be a factor here since we are dealing with a visual feedback control that fixates the gaze. This variable(s) could be called C_f (for central fixation).

d. Another group of variables consist of: Psychological processes (such as waxing and waning, mental blankness, pleasant mood), patients' feedback, motivation, etc.

In order to minimize these factors as much as possible patients were made aware of these conditions and were interviewed after some of the questionable readouts.

When designing this experiment, the author was faced with a difficult task in deciding what control group is the most appropriate. A control is chosen by keeping all variables constant, and then one or more factors are manipulated or systematically varied and finally any changes caused by manipulation of those factors are being measured. In the study of alpha rhythm, it is not possible to choose another subject to act as a control when the objective of the research is to watch the changes in the alpha amplitude under certain conditions, because of many inter-individual variabilities (see previous discussion). For this reason I chose to utilize the same subject who receives treatment to be his own control.

1. For example, when the subject is instructed to centrally fixate with the amblyopic eye, he is actually receiving a treatment, and when he/she is asked to "habitually" fixate with that eye, he/she is becoming a control for the study. On the other hand, when this subject is tested with his/her non-amblyopic eye under exactly the same instructions, we are actually looking at a separate population of subjects. Here we would like to find out to what extent the reduction of the amplitude of alpha is influenced by factors such as anxiety to do something right, motivation, attention, alertness, etc. By subtracting the t-value of the amblyopic eye effect from t-value of the non-amblyopic eye, we reach the "experiment magnitude effect." Additional very useful information is obtained by comparing the scores of each eye on the first day (pre-test) with the scores resulting on the last day (post-test). Here we are more concerned with changes in the magnitude of eccentric fixation due to the "training." Clinically, the instrument used in this experiment

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for fixation target (MITT), is used as an in-office visual training device for eccentric fixation, therefore, it is possible that during the one-month training period given to these subjects, they have improved their amblyopic eye by more centrally fixating. Another t-test that compares the means of pre-tests for all six subjects with the post-tests is done to find the effects of "maturation" as a result of "visual training" for this population. The pre-test/post-test comparison is done for both "A" and "NA." Theoretically, if "treatment" produces some lasting effect on the experimental group, this influence should also be seen in our control group. For example, if the subject is achieving some degrees of central fixation due to visual training, that improvement should manifest itself even if he is not trying to centrally fixate. This means that ideally post-test "A" and "NA" should show an improvement from pre-test "A" and "NA" simultaneously. This t-test only tells us whether or not a significant difference existed between pre-test and post-test.

2. Another comparison could be made between "NA's" of both populations. Here we are interested to know what happens to our control groups in the absence of "treatment." A significant t-test in this case could mean that alpha decreases in amplitude regardless of our "treatment" (central fixation), whereas an insignificant finding suggests to us that "treatment" should have made some difference to our experimental groups.

3. As mentioned before, for the non-amblyopic eye it is

useful to make a comparison between "A" and "NA" to find out how psychological factors of our instructions could influence the outcome of our study.

4. Finally, an inter-population comparison is made between "A" of the amblyopic eye and "A" of the non-amblyopic. Although apparently we are comparing two separate populations, the only useful information gained from this comparison is that whether our "treatment" is successful to bring the level of the amblyopic eye up to the non-amblyopic eye.

Graphical Studies

Interactions: When the means of the "index of fixation" are plotted for attempt and no attempt for central fixation, an interaction graph will result. This graph consists of two lines. If these two lines appear parallel, there seems to be no interaction, whereas an unparallel or cross pair of lines suggest interaction.

Interpretation of Data

1. Criteria for an acceptable trace:

a. Noise (see preceding): A trace that showed many artifacts was not used for statistical analysis.

b. Alertness and fatique of the subject: If the subject was excessively tired and not very alert, the recording was not done at that session.

c. Abundance and frequency of α-rhythm: Some other brain waves could mimic α such as Lambda, Mu and Theta. Special care was taken to rule out these traces.

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2. Averaging the alpha rhythm amplitude. The method was discussed previously.

3. Calculating the "index of fixation"* for "attempt" and "no attempt" runs.

4. Finally calculating the average of the "indices of fixation" for each subject throughout the experiment.

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*I have made up this term for referring to the ratio of alpha amplitudes when the subject is looking at the letters of the MITT screen (attempt to centrally fixate or just eccentrally fixating) over the amplitude while looking at a gray screen in the distance.

Results

1. Statistical Analysis

As previously mentioned alpha rhythm is influenced by many psychological and physiological variables. As in any other behavioral experiments, these factors do not seem to be too important because sometimes these variables can simultaneously belong to two or three categories and makes it impossible to classify them. Then, there only remains one independent variable: central fixation (attempting to put HB on the letter by looking to the side of letter) and one dependent variable: alpha-rhythm amplitude. For simplifying our statistical analysis and for the sake of minimizing intra-individual variables, as it was already discussed, I chose to utilize the ratio of attempt/amplitude fixation of distance and no attempt/amplitude fixation distance as index of fixation. Therefore, we are dealing with four groups: two trials for the amblyopic eye and two trials for the sound eye for all six subjects.

2. Data

Each strip chart of alpha rhythm for subjects were analyzed as previously mentioned (pp. 21-6). Results were averaged and divided into four subgroups.

$G_1 = \overline{X}_{AEA}$ = Mean ratio of alpha rhythm amplitude when attempting to centrally fixate by the amblyopic eye.

$G_2 = \overline{X}_{AENA}$ = Mean ratio of alpha rhythm amplitude while no attempt was made for central fixation by the amblyopic eye.

$G_3 = \overline{X}_{SEA}$ = Mean ratio of alpha rhythm amplitude when "attempting to centrally fixate"* with the non-amblyopic (sound) eye.

$G_4 = \overline{X}_{SENA}$ = Mean ratio of alpha rhythm amplitude while "no attempt was made for central"* fixation by the sound eye.

a. <u>One-tailed t-test</u> was used for statistical analysis. Four subsections for t-test computation were taken into consideration. These interactions were: G_1XG_2, G_1XG_3, G_3XG_4 and G_2XG_4.

b. Degrees of freedom chosen for G_1XG_2 and G_3XG_4 was 5 (n-1) since the treatment was given to the same eye (AE or SE). For G_1XG_3 and G_2XG_4 df was 10 $(n_1 - 1 + n_2 - 1)$ since two different eyes were compared.

c. Alpha level was chosen at .05.

The analysis of the t-test data reveals a significant effect of $t(G_1, G_2) = 7.00 \; \alpha < .0005$ and $t(G_3, G_4) = 3.25 \; \alpha < .025$, but not as significant $t(G_1, G_3) = 1.50 \; \alpha < .10$ and an insignificant $t(G_2, G_4) = .27 \; \alpha > .10$.

d. Assumptions.

1. The variable is normally distributed in each of

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*For the sound eye G_3 and G_4 are theoretically the same situation. But other influences could exist. Please refer to the discussion.

	Subjects	G_1 $\overline{X}_{AEA}$	G_2 $\overline{X}_{AENA}$	G_3 $\overline{X}_{SEA}$	G_4 $\overline{X}_{SENA}$
V.G.	1	1.04	1.12	1.11	1.32
B.J.	2	1.10	1.21	0.81	0.92
M.L.	3	1.22	1.18	1.09	1.13
B.S.	4	0.99	1.14	0.93	1.13
J.T.	5	0.98	1.01	0.84	0.88
E.W.	6	1.13	1.22	1.14	1.32

Table 1. Table of average "fixation index" of four subgroups.

	G_1	G_2	G_3	G_4
SD	.09	.08	.15	.19
$\overline{X}$	1.08	1.15	.99	1.12
n	6	6	6	6
EX^2	7.00	7.92	5.95	7.66
EX	6.5	6.9	5.9	6.7

Table 2. Standard deviation and mean of four subgroups.

$$t \quad \frac{\bar{X}_m - \bar{X}_n}{Sd_m - SD_n}$$

t-grouping	t-results	df	α
G_1XG_2	7.00	5	$<.05$
G_1XG_3	1.50	10	$>.05$
G_2XG_4	.27	10	$>.05$
G_3XG_4	3.25	5	$<.05$

Table 3. T-test

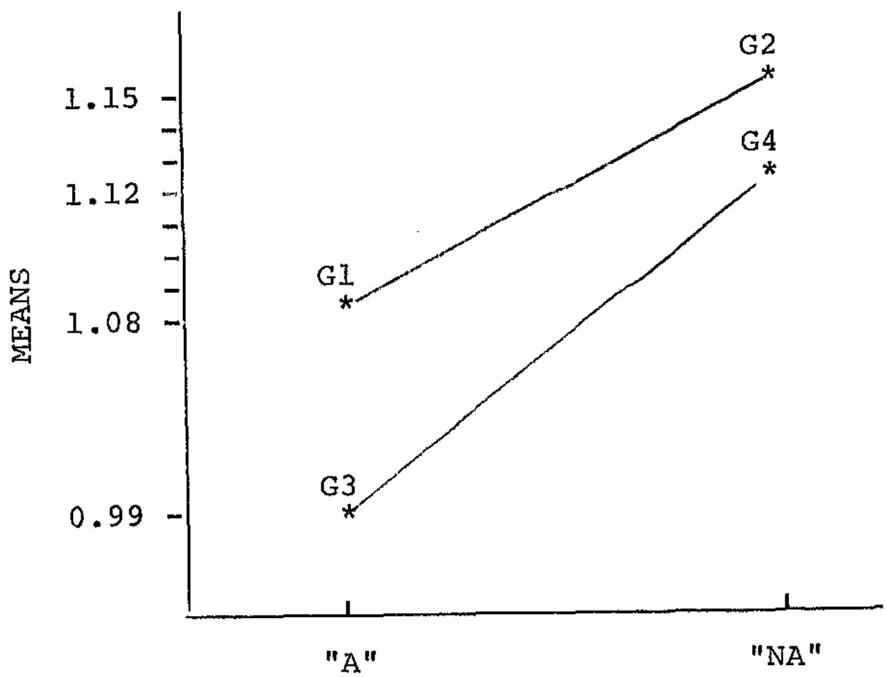

Fig. 4. Graphs for interaction effects

Gender	Attempt		No Attempt	
	1.04		1.12	
	1.10	$n_1=6$	1.21	$n_3=6$
	1.22	$EX_1=6.5$	1.18	$EX_3=6.9$
Amblyope	.99		1.14	
	.98	$EX_1^2=7.00$	1.01	$EX_3^2=7.92$
	1.13	$\overline{X}_1=1.08$	1.22	$\overline{X}_3=1.15$
	1.11	$n_2=6$	1.32	$n_4=6$
	0.81	$EX_2=5.9$	0.90	$EX_4=6.7$
Non-amblyope	1.09		1.13	
	.93	$EX_2^2=5.95$	1.13	$EX_4^2=7.66$
	.84	$\overline{X}_2=.99$	.88	$X_4=1.12$
	1.14		1.32	

Table 4. Average of "index of fixation" for each subject's amblyopic eye categorized at "attempt" and "no attempt" fixation status.

Source of Variation	df	Sum of Squares	Mean Squares	F
Between Groups	(3)	(.09)		
Gender	1	.02	.02	2^a
"Attempt" Status	1	.05	.05	5^b
GXS	1	.02	.02	2^a
Within Groups	20	.27	.01	

$^a P > .05$ Accept Ho

$^b P < .05$ Reject Ho

Table 5. ANOVA table for the two independent variables of gender and control fixation attempt status.

the four groups: Satisfied, i.e., at least 68 percent of the population in each group falls within 1 sd. from the mean.

2. The standard deviations are approximately equal in each of the four samples: Unsatisfied (these assumptions are robust and can be violated without seriously affecting the outcome of the research).

3. Non-amblyopic eye utilizes more neurons than the eccentrically fixating amblyopic eye.

4. When taking the ratio of amplitude of alpha rhythm while the subject attempts to centrally fixate or the amplitude while "habitually" fixating, over the amplitude of alpha while the subject is looking in the distance at a gray screen, the variables such as auditory, proprioceptive, tactile, passive movements of the body and eyes, personality, intelligence and abundance or scarcity of alpha rhythm are cancelled out.

5. Other variables such as age, sex, mental blankness, moods, etc., do not appear to alter the results.

	Pre-test		Post-test	
Subjects	AEA	AENA	AEA	AENA
V.G.	.55	.79	1.31	1.50
B.J.	.75	.77	.92	1.00
M.L.	1.76	1.45	.91	.98
B.S.	1.19	1.54	.70	.78
J.T.	.78	.78	1.09	1.25
E.W.	1.00	1.48	1.37	1.47
EX	6.03	6.81	6.30	6.98
EX^2	6.96	8.48	6.98	8.52
$\overline{X}$	1.01	1.14	1.05	1.16
$\overline{X}^2$	1.17	1.41	1.16	1.42

Table 6.

1. Comparison of pre-test AEA and post-test AEA

   t (1.01, 1.05) = $.28\ \alpha < .05$ statistically insignificant.

2. Comparison of pre-test AENA and post-test AENA

   t (1.41, 1.42) = $.31\ \alpha < .05$ statistically insignificant.

Conclusions from the Data

The results from the statistical analysis performed in this study may indicate a significant decrease in the amplitude of the alpha rhythm while the subjects are "attempting" to centrally fixate by placing a Haidinger Brush on the fixation target when viewing an entoptic phenomenon on the screen of MITT.

1. Of the most interest to us in this study is $t\ (G_1, G_2) = 7.00\ \alpha < .0005$. This tells us that with a very high confidence that "treatment" has had an effect on our experimental group. That effect is a decrease in the amplitude of alpha rhythm. This result is what we had hoped for when designing this study. Our pre-test/post-test comparison which was done on the findings for G_1 and G_2 in order to find any "maturation" (or training) effect which could decrease the confidence of our above finding, proved that indeed subjects have not decreased their alpha rhythm as the result of "training" effect. This later t-test [$t\ (.05, .10) = .27\ \alpha > .10$ insignificant] could add to to the confidence of our results.

2. $t\ (G_2, G_4) = .27\ \alpha > .10$. This finding would suggest to us that for both the amblyopic eye and the non-amblyopic eye which were used as control groups, α-rhythm was not affected (decreased). This result supports our hypothesis that central fixation could decrease the amplitude of alpha rhythm.

3. $t\ (G_3, G_4) = 3.25\ \alpha < .025$. This is the case that decreases the confidence of our findings in (1) because it suggests that although the non-amblyopic eye was always centrally fixating during "A" and "NA," the amplitude of alpha has decreased significantly. Since in the case of "A" and "NA" for the non-amblyopic eye, the only variable that was changed had been our instructions to the subject: (A: "try to keep the HB steadily on the letter." NA: "Just look at the letter."), any change in the amplitude could be attributed to psychological effects such as anxiety, motivation, alertness and attention in the "A." In order to calculate the experiment magnitude effect:

$t\ (G_1, G_2) - t\ (G_3, G_4) = 7 - 3.25 = 3.75\ \alpha < .01$.

From this result we may conclude that after the psychological effects of our instructions have been subtracted from the decrease in the alpha amplitude as happened when the amblyopic eye had tried to centrally fixate, still the final outcome is statistically significant.

4. The results of $t\ (G_1, G_3) = 1.50\ \alpha < .1$ is the least useful comparison we could make, since the two populations compared are really different. It means that with 90 percent confidence the amblyopic eye with "treatment" could attenuate the α-activity to the same level as the non-amblyopic eye.

Graphical Representation

1. Interaction: Linear representation of interaction

of the amblyopic eye and the non-amblyopic eye with the treatment and no treatment was shown in Figure 4, and a two-factor design ANOVA was done to determine the level of significance of the interaction between groups (Tables 5 and 6). As shown in Table 6, the results of ANOVA between groups for gender (amblyopia vs. non-amblyopia) and GXS (gender x status of fixation) were not significant at .05 level but central fixation status was shown to be significant ($p < .05$).

Summary of Conclusions

Alpha rhythm amplitude appears to decrease when an eccentrically fixating amblyope attempts to centrally fixate. Creutzfeldt (1969) once correlated the number of neurons being "synchronized" with the potential for alpha activity (e.g., attenuation with attention). It appears to be safe to assume that the non-amblyopic eye utilizes more neurons than the amblyopic eye. On the basis of this assumption, it is probable that central fixation triggers more neurons to actively participate in attenuation of the alpha activity. This study may be replicated by utilizing more subjects perferably within the same age group and equal distribution of sex (in the present study there were twice as many males than females). Optimally, the external variables should be more controlled (e.g., auditory, tactile, etc.). Finally, the use of a conputerized device (e.g., Biomac 1000) would help the experimenters to analyze the amplitude of the alpha rhythm more quickly and accurately.

If upon such investigation, central fixation for eccentrically fixating amblyopes proved to have a direct correlation with the attenuation of the alpha rhythm, then it is possible to invent a device that utilizes this concept and gives the subject an auditory biofeedback when centrally fixating.

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